Model-Based Motion Tracking of Infants

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Using a model-based approach, we are able to model and track the movements of infants, based on 3D data obtained from the Microsoft Kinect Sensor. This is done by modeling the surface of the infants as a set of connected 3D primitives and optimizing the underlying state parameters, in order to fit the model to the observed 3D data.

Model Description

The 3D model is simply based on defining and connecting 3D primitives and thus the parameters of the 3D model are spatial locations. However, in order to naturally constraint and model movements, the spatial locations are based on angles and limb sizes. These state parameters only contain one set of spatial parameters, namely the global orientation of the body model, while the location of all other limbs are based on the global position and the respective joint orientations. The location of the hand is thus a combination of; the length and rotation of the lower arm and the upper arm, the size of the chest, and the global position of the body.

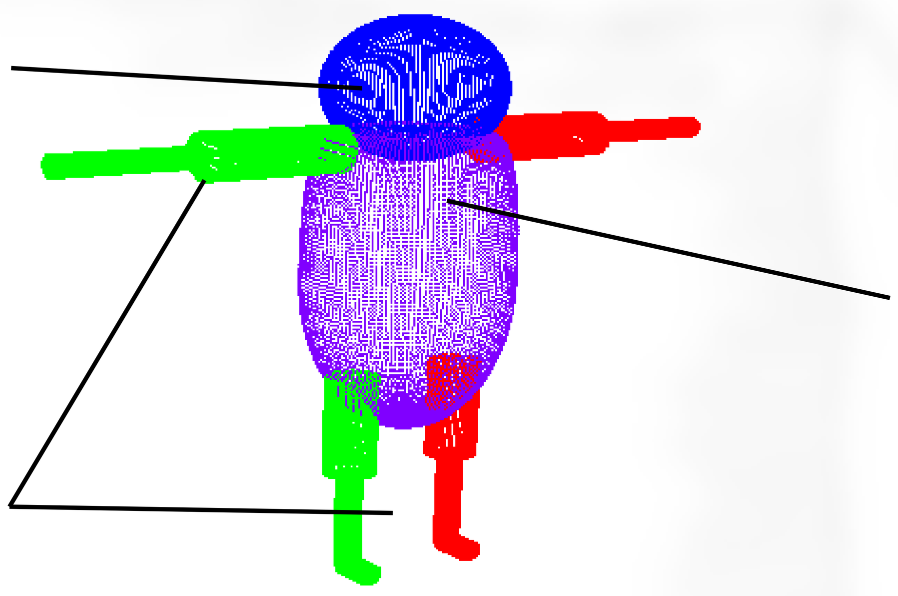

Figure 1: The 3D model used in this work is visualized. The different parts of the model are shortly explained in terms of how the distance between the model and observation points are calculated.

Body part	Parameters
Stomach	Rotation (3), Position (3)
Head	Rotation (3)
Left Upper Arm	Rotation (3)
Right Upper Arm	Rotation (3)
Left Lower Arm	Rotation (3)
Right Lower Arm	Rotation (3)
Left Upper Leg	Rotation (3)
Right Upper Leg	Rotation (3)
Left Lower Leg	Rotation (3)
Right Lower Leg	Rotation (3)
Left Foot	Rotation (3)
Right Foot	Rotation (3)

Table 1: The number of parameters used for each body part. The stomach body part is the only one containing position parameters, as all other body parts are connected to the stomach, through their parent body parts.

Size fitting

Initially, the size of the different body parts are based on sizes of the average infant (based on studies on anthropometry of infants). However, in order to fit the model correctly to the individual infants, the size parameters are optimized in a calibration step. Her, both orientation and size parameters are updated, but the optimization is based on segments of the observed 3D data. The segmentation is based on a graph-based human tracking approach [1], which is able to segment and differentiate between head, Left/Right arms and Left/Right legs.

The size parameters of the upper body are optimized based on the segmented arms and the head, while the size parameters of the lower body limbs are based on the segmented legs.

GPU Speedup

As described, the Jacobian matrix is approximated during the optimization step and each row of the Jacobian matrix is based on one observation point. Because of this, the calculation of the Jacobian elements is done on the GPU, where each thread of the GPU relates to one observation point.

Optimization

In order to fit the model to the observed 3D data, the state parameters are optimized using the Levenberg-Marquardt optimization scheme. To quickly summarize, this optimization scheme iteratively updates the state parameters using a combination of the gradient descent method and the Gauss-Newton method. The state parameters are updated such that some objective function is minimized. In this study, the objective function is defined as the sum of squared distances between the observed 3D data and the surface of the 3D model. As the model is defined as a set of simple primitives, the distances are found as the minimum distances between each of the primitives and the individual observed 3D data. The Levenberg-Marquardt method requires the Jacobian matrix and this is approximated using forward differences. This results in one residual evaluation for each optimization parameter, where each element $J_{i,j}$ of the Jacobian matrix $\boldsymbol{J}$ defines how the i'th element of the residual, changes with respect to the j'th state parameter.

Conclusion

We have presented a model-based motion tracking method for infants. We see how the method is able to locate and track the different body parts of the infant. In future work, we will use these result to analyze the movements of infants and see if movement impairing diseases, such as cerebral palsy, can be detected automatically.

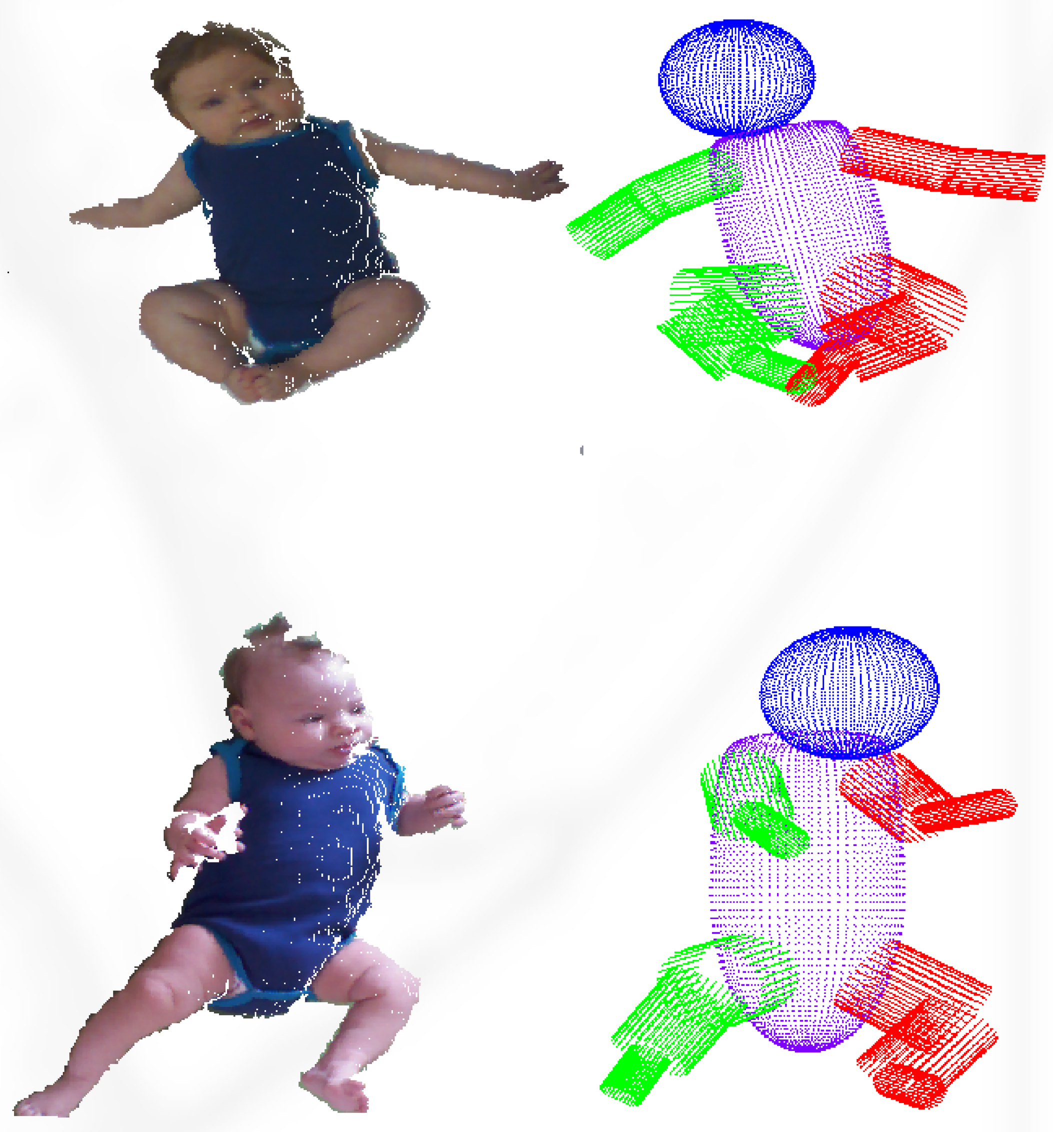

Figure 2: Some of the results from the tracking can be seen above, where the 3D model(right) has been fitted to the respective frame data (left).

[1] Estimating Human 3D Pose from Time-of-Flight Images Based on Geodesic Distances and Optical Flow
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